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Risk Evaluation of Regional Collapses Geological Hazard Based on D-S Evidence Theory

——A case study of Haiyuan active fault belt in Ningxia Province

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Abstract

At the regional collapse of geological hazard evaluation process, in the selection of evaluation factors and determination of the weight, there are subjectivity, uncertainty, and many other issues. In this paper, the Haiyuan fault belt in Ningxia Province is the study area, respectively, with D-S evidence theory and fuzzy comprehensive evaluation methods to build a collapse of geological hazard assessment model, presented Concrete evidence theoretical algorithm. The application results show that the evidence theoretical evaluation model compared to fuzzy comprehensive evaluation model is more reliable and accurate. It solved the uncertainty evaluation issues.

Keyword: D-S evidence theory; Fuzzy Comprehensive Evaluation; AHP; Collapse; Geological Hazard Evaluation

1. Introduction

The western region of geological disasters, mainly collapse, landslides, mudslides and ground cracks. Active faults in the region are well developed, its intensity and the number is far greater than the eastern region. The Institute for the selected study area is famous Haiyuan active fault; fault activity within the study area is very frequent, we can determine the vast majority of the study area geological disasters to some extent with the activities of active faults association. However, the formation mechanism of

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geological hazards is more complex, the effects of factors, there is uncertainty [1].

Regional geological hazard assessment methods commonly used in quantitative fuzzy comprehensive evaluation method, artificial neural network method, multivariate statistical methods, the amount of information law, the right to information law, which use more fuzzy comprehensive evaluation method. Fuzzy comprehensive evaluation method is mainly targeted at specific and detailed evaluation of the sample and determines the factors in the selection and evaluation of factors to determine the weight of each factor there is random and subjective process, not a good solution to the problem of uncertainty evaluation. The D-S evidence theory is a method of uncertainty reasoning in artificial intelligence, can solve the problem of uncertainty.

2. D-S evidence theory and principles to improve the synthesis

2.1. Basic theory of D-S

D-S evidence theory, also known as Dempster-Shafer theory, dealing with uncertainty is an important method. D-S evidence theory is an extension of classical probability theory, with a more complete mathematical theory, the theory of measurement uncertainty in people's habits of mind close to full utilization of redundant information, better integration of evidence from multiple source of information, in practical applications has achieved fruitful results.

D-S evidence theory is based on non-empty finite field Θ on the theory. Framework for the identification Θ, ie the sample space, that limited the system state $\{\theta_1, \theta_2, \dots, \theta_n\}$ and independent of each other. There is only one element, and θ^* is the problem Q, the correct answer. Assume that policy makers hope to find evidence for some θ^*. As evidence of incomplete, inaccurate, or other reasons not entirely reliable, policy-makers may be unable to determine θ^*, but based on some evidence to varying degrees, to determine the scope of their varied θ^* is possible. Based on this idea, Shafer defines the concept of mass function [2].

2.2. D-S rule synthesis

Let Bel_1, and Bel_2 identification framework Θ is the same on the two belief function, m_1 and m_2 are the corresponding basic probability assignment function, focal element are $A_1, A_2, \dots, A_k$ and $B1, B_2, \dots, B_l$

$$m_1 \oplus m_2(A)=\begin{cases} 0 & A=\Phi \\ \dfrac{\sum\limits_{A_i \cap B_j = A} m_1(A_i)m_2(B_j)}{1-\sum\limits_{A_i \cap B_j = \Phi} m_1(A_i)m_2(B_j)} & A \neq \Phi \end{cases} \tag{1}$$

Mass function of the synthesis of n rules: For, $A \neq \Phi$

$$(m_1 \oplus m_2 \oplus \dots \oplus m_n)(A)=K_n \sum_{A_1 \cap A_2 \cap \cdots \cap A_N} m_1(A_1)m_2(A_2)\cdots m_n(A_n) \tag{2}$$

Among,

$$K_n = 1/N_n, \; N_n = \sum_{A_1 \cap A_2 \cap \cdots \cap A_N \neq \phi} m_1(A_1)m_2(A_2)\cdots m_n(A_n) \tag{3}$$

2.3. Improved synthesis rules

So that $\Theta = \{\theta_1, \theta_2, ..., \theta_n\}$ for the identification box, assuming that there are r information sources $E_1, ..., E_r, E_i$ sources of information The information provided is $\theta_j \in \Theta$ with confidence β_{ij} is true ($i = 1, ... , r; j = 1, ..., n$), confidence β_{ij} met $\sum_{i=1}^{n}\beta_{ij} \le 1, i = 1,\cdots,r$. In addition, r is not necessarily as important information sources, and set Ei relative weight W_i $(i = 1, ..., r)$, to meet $\sum_{i=1}^{r} w_i = 1, w_1,\cdots,w_r \ge 0$, following the evidence reasoning model to obtain the improved synthesis of law on the recognition of each frame Θ the credibility of the proposition.

First assigned to Θ basic credibility within the value proposition, and the establishment of evidence, the weight vector $W = (w_1, w_2, ..., w_n)$. Second, set $w_{max} = max \{w_1, w_2, ..., w_n\}$, the relative weight vector can have $W' = (w_1, w_2, ..., w_n) / w_{max}$, to determine the credibility of the evidence of the basic discount rate α_i $(0 \le \alpha_i \le 1)$, $(1-\alpha_i) = w_i / w_{max}$, $i = 1,2, ..., n$. With this discount rate to adjust the basic credibility of the distribution function,

$$m_i(A_k) = (1-\alpha_i)m_i(A_k), m(\Theta) = (1-\alpha_i)m(\Theta) + \alpha_i \quad (4)$$

Where: $k = 1,2, ..., d_i$, d_i E_i evidence recognition framework provided the basic credibility of the Central African Θ number. All the propositions of the evidence will be adjusted values into the basic credibility of the integration formulas, integration of new evidence would constitute a formula[3].

3. Regional evaluation of geological hazard landslides

This Haiyuan fault activity for the study area, study area, the use of 1.5km × 1.5km grid to grid, based on the base maps of 1:50000 geological maps, the region is divided into 1080 units.

Step is to use mathematical methods to achieve each evaluation unit of the collapse of the risk assessment of geological disasters, to get different levels of evaluation results, and then use ArcGIS software to map the grid of colors with different evaluation of the results of Fig.

3.1. Fuzzy comprehensive evaluation method based on regional avalanche risk assessment

The results of geological hazard assessment into severe danger zone corresponding to moderate and mild danger zone danger zone.

Collapse of growth factors affect the intensity of the main geological conditions, power conditions and the collapse of the status quo. So I chose the following 10 factors established evaluation factors set, $U = (F_1, F_2, ..., F_{10})$ = {slope height, slope, lithology, the number of active faults, rainfall, groundwater conditions, seismic intensity, the maximum depth of excavation works , covering an area of accumulation body collapse, collapse disaster losses}.

Assumed that $\alpha_1, ..., \alpha_m$ are evaluation factors $u_1, ..., u_m$ weight, and meet $\alpha_1 + ... + \alpha_m = 1$, so that $A = (a_1, a_2, ..., a_m)$, then A is reflected in the factor weights of fuzzy sets (the weight vector) [4].

Collapse developmental evaluation should establish two levels of intensity of the structural model. Method using 1-9 scale factor of the various layers of the target level on the relative importance of a pairwise comparison matrix to determine the structure. And calculate the largest eigenvalue, eigenvector corresponding to each level of the single judge order, and matrix consistency test, the results are as follows: $\underline{A} = [0.059\ \ 0.065\ \ 0.131\ \ 0.145\ \ 0.178\ \ 0.063\ \ 0.053\ \ 0.106\ \ 0.1\ \ 0.1]$

Evaluation set $V = \{V_1, V_2, V_3\} = \{I, II, III\}$ = {mild danger zone, moderate risk areas, serious danger zone}. Criteria determined mainly by the expertise.

According to geological hazard evaluation system and grading standards, obtained fuzzy evaluation matrix of membership values, its desirability as a trapezoidal membership function distribution function.

Following an evaluation unit, for example to establish the fuzzy evaluation matrix to illustrate the unit, such as a landslide hazard evaluation units of its evaluation of various factors is required: slope height: 15m, slope: 30°, lithology: 0.6, live The number of faults: 1, rainfall: 200 mm, groundwater conditions: 0.2, the earthquake intensity: 4, maximum excavation depth engineering: 15m, covering an area of accumulation body collapse: 500 m^2, collapse disaster losses: 0.5

The value will be substituted into the trapezoidal membership function, each factor is worth the membership to three, corresponding to the three risk assessment of the level of collapse, all the factors is worthy of membership to fuzzy matrix.

Weight vector by the matrix and fuzzy "synthetic" has been integrated membership B, namely, by fuzzy operation $\underline{B}=\underline{A}\circ\underline{R}$, find fuzzy set $\underline{B}=(b_1, b_2, \cdots, b_n)(0\leqslant b_j\leqslant 1)$, which $b_j=\sum_{i=1}^{m}\mathrm{airij}(\mathrm{M}(\bullet,+))$ [5] . Using the above example is calculated to be $\underline{B}=\underline{A}\circ\underline{R}=[0.4301\ \ 0.5699\ \ 0]$

Based on the maximum degree of membership criteria, the corresponding level of risk classification is i_0. Then b_i=0.5699, hazard evaluation grade II, unit operations in all evaluation results obtained by the figure, respectively, red, yellow, green areas to represent the collapse of disasters, serious, moderate and mild danger zone. Figure 1 shows the study area collapse of geological hazard evaluation results.

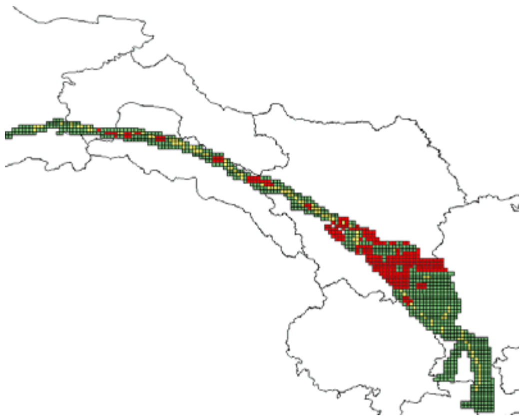

Fig. 1. Evaluation results

3.2. D-S evidence theory based on risk assessment of the regional collapse

3.2.1. Establishing an evaluation set V

Evaluation set $V = \{V_1, V_2, V_3\} = \{I, II, III\}$ = {mild danger zone, moderate risk areas, serious danger zone}. Fuzzy said Table 1.

Table 1 Evaluation index fuzzy value

Evaluation results	Evaluation fuzzy set
Mild risk	[0.00,0.33]
Moderate risk	[0.33,0.66]
Severe risk	[0.66,1.00]

3.2.2. Determine the mass function

Design of the questionnaire, the experts repeatedly asked for the evaluation of various risk factors may be ticked, so $P_j(X)=\{P_j(x_1),P_j(x_2),P_j(x_3)\}$for the expert evaluation factors are given j, the probability of the risk level. Mass function:

$$m_j(x)=\begin{cases}P_j(x_1),x=x_1\\P_j(x_2),x=x_2\\p_j(x_3),x=x_3\\P_j(\Theta),x=\Theta\end{cases} \tag{5}$$

$P_j\ (X_i)\ (i = 1,2, ..., 5)$, evaluation results for the fuzzy set corresponding to the probability of X_i, and its value in the range $0 \le P_j\ (X_i) \le 1$, $P_j\ (\Theta)$ experts on the factors j evaluation of the results of uncertain probability[6].

3.2.3. Distribution of tables to establish credibility

Single factor derived from the previous weight and mass function, available in Table 2.

Table 2 mass function

Factor set	Weight	x_1	x_2	x_3	Θ
F_1	W_1	$P_1(x_1)$	$P_1(x_2)$	$P_1(x_3)$	$P_1(\Theta)$
F_2	W_2	$P_2(x_1)$	$P_2(x_2)$	$P_2(x_3)$	$P_2(\Theta)$
…	…	…			

3.2.4. Improved Synthesis of rule-based information

The synthesis of m_1 and m_2 example, $m\ (A)$ and $m\ (B)$ for the basic credibility of the m_1 and m_2, the specific algorithm is as follows:

$$Y_1=\sum_{A_i \cap B_j = A} m_1(A_i)m_2(B_j),\ Y_2=\sum_{A_i \cap B_j = \Phi} m_1(A_i)m_2(B_j) \tag{6}$$

For m_1 and m_2:

$$Y_1=m_1(x_1)m_2(x_1)+m_1(x_1)m_2(\Theta)+m_1(\Theta)m_2(x_1) \tag{7}$$

$$Y_2= m_1(x_1)m2(x_1)+m_1(x_1)m_2(\Theta)+m1(\Theta)m_2(x_1)+ ... + m_1(x_3)m_2(x_3)+m_1(x_3)m_2(\Theta)+m_1(\Theta)m_2(x_3) \tag{8}$$

$m(x_1)=Y_1/Y_2$, And so on, can get $m(x_2)$, $m(x_3)$. Synthesis of the results and then turn to other evaluation factors synthesized, end up affecting the risk likelihood and risk the consequences of two layers of synthetic target value [6].

3.2.5. Evaluation results

The calculation of this risk assessment units for the 0.5832 level of probability, belong to moderate risk areas, the evaluation unit calculated after all, that can be drawn in the study area landslide hazard assessment evaluation results. Results displayed in ArcGIS map, respectively, red, blue, green areas to represent the collapse of disasters, serious, moderate and mild danger zone. Figure 2 shows the study area collapse geological hazard evaluation results.

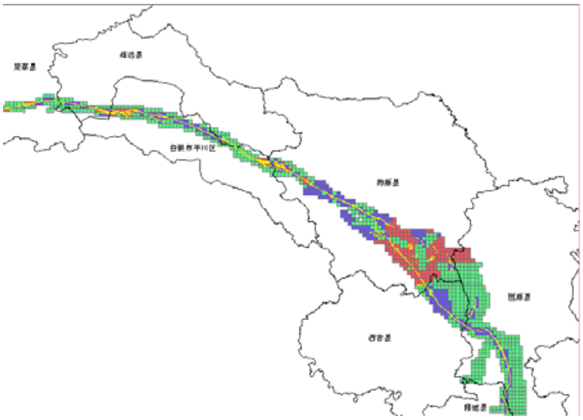

Fig. 2. Evaluation results

4. Comparison of two methods

Based on D-S evidence theory method and fuzzy comprehensive evaluation method, respectively, of the study area of the evaluation unit collapse risk assessment, by comparison, in the text of a specific evaluation unit for evaluation, based on D-S evidence theory approach than fuzzy comprehensive evaluation method to determine moderate risk areas are more likely to 0.0133, more certain. In evidence theory, risk assessment survey questionnaire by adding uncertain options, better able to express the uncertainty of the experts, more humane. Therefore, it can be drawn based on D-S evidence theory of geological hazard assessment method than fuzzy comprehensive evaluation method has a higher reliability and accuracy.

References

[1] Highway to active faults and fissures of the fine detection, hazard assessment and control techniques - the feasibility study report, Chang'an University, 2004

[2] Duan Xinsheng,Evidence theory and decision-making, artificial intelligence [M], Beijing: China Renmin University Press, 1993

[3] Gao Huisheng, Zhu Jing,Based on DS evidence theory of network security risk assessment model [J], Computer Engineering and Applications, 2008,44 (6)

[4] Zhuang Suofa,AHP-based comprehensive evaluation model, Hefei University of Technology (Natural Science Edition), 2000,23 (4)

[5] Shen Fang,Mountain geological environment evaluation and geological hazard zonation of the GIS system, Chengdu University of Technology, Ph.D. thesis, 2000.6

[6] Hu Zikang, Wang Yongxian, Zhu Tao, Evidence-based reasoning to improve the multi-attribute decision making model [J], Operations Research and Management, 2006. 15 (6)